Intensional Models

Let L be a DRS language with a family Rel^n of atomic predicates and a set $\mathcal{N}$ of names. We say that an *intensional model M for L* is a triple $\langle W_M, U_M, I_M\rangle$, where

- W_M is a set of possible worlds;
- U_M is a non-empty set;
- $I: \mathcal{N} \to \{\{d\}|d \in U_M\}$, and $I: Rel^n \to (W_M \to \mathcal{P}(U_M))$.

Verifying embeddings are given *globally*, i.e. $g: X \to U_M$. Intensional semantics for DRS-es and the DRS-conditions we have handled so far: **Exercise**. Assuming a total accessibility relation on W_M, we have in addition:

(1) a. $g \models_{M,w} \Box K$ iff $\forall w' \in W_M: g \models_{M,w'} K$;
b. $g \models_{M,w} \Diamond K$ iff ...

NB1 for those familiar with work on modality in Dynamic Semantics: the modalities in (1) are not *epistemic* modalities. *Might* in DS: a consistency check on context, as in (2). The clauses in (1) serve different purposes.

(2) It *might* be raining. It isn't raining.

NB2 Times in DRT:
Now assume: L contains in addition

- discourse referents for times, events and states;
- constants $\prec, \circ, \subseteq, :$ (complete precedence, overlap, temporal inclusion, 'is of type') and perhaps others.

An *intensional* model M for L is now of the form $\langle W_M, \mathcal{T}_M, E_M, S_M, U_M, I_M\rangle$; $E_{M,w}, S_{M,w}, Per(\mathcal{T}_M) \subseteq U_{M,w}$ for $w \in W$;

Definition 1 A DRS K is *true in M in w at t* iff there is a verifying embedding f of U_K into $U_{M,w}$ such that

1. f verifies all conditions of K in M in w, and
2. $f(n) \subseteq t$.

Information States and Context Change Potentials

Definition 2 Information states: given M, DRS K and a set X of dref-s,

1. s is an information state (i.s., henceforth) relative to M and X iff $s \subseteq \{\langle w, f\rangle | Dom(f) = X \ \&\ Ran(f) \subseteq U_M \ \&\ w \in W_M\}$.
2. s is an i.s. relative to M iff there is a set X of drefs s.t. …;
3. X is the *base* of s; notation: X_s;
4. the empty information state: $\Lambda^s_M =_{df} \{\langle w, \Lambda\rangle | w \in W_M\}$;
5. The proposition determined by s: $Prop(s) =_{df} \{w | \exists f\colon \langle w, f\rangle \in s\}$.

Given a proper DRS, the *information state* $[\![K]\!]^s_M$ *expressed by* K *relative to* M*:*

(3) $[\![K]\!]^s_M =_{df} \{\langle w, f\rangle | \langle \Lambda, f\rangle \models_{M,w} K\}$.

Definition 3 Given: an intensional model M, a possibly improper DRS K and an assignment g of $FV(K)$ in M. Then

1. *the proposition expressed by* K *relative to* M, g,
   $[\![K]\!]^p_{M,g} =_{df} \{w \in W | \exists h\colon g \subseteq_{U_K} h \ \&\ \langle g, h\rangle \models_{M,g} K\}$;
2. the information state expressed by K relative to M, g,
   $[\![K]\!]^s_{M,g} =_{df} \{\langle w, h\rangle | g \subseteq_{U_K} h \ \&\ \langle g, h\rangle \models_{M,w} K\}$.

Definition 4 The *Context Change Potential* $[\![K]\!]^d_M (= \pi_K)$ of a DRS K relative to model M is a partial function from i.s-s to i.s.-s s.t.:
$[\![K]\!]^d_M =_{df} \in S^{S'}$, where $S' \subseteq S$, s.t.

1. $s \in Dom([\![K]\!]^d_M)$ iff $FV(K) \subseteq X_s$;
2. if $s \in Dom([\![K]\!]^d_M)$, then
   $[\![K]\!]^d_M(s) = \{\langle w, g\rangle | \exists f\colon (\langle w, f\rangle \in s \ \&\ \langle f, g\rangle \models_{M,w} K)\}$.

If K is proper, $[\![K]\!]_M^d$ is a total function. That is, it will be defined even for the empty i.s. Λ_M^s.

Merging information states:

Definition 5 Given an intensional model M and a set S of is-s relative to M, the *consistent merge* of the members of S, denoted $\underline{\bigcup} S$, is the information state defined by:
$\underline{\bigcup} S =_{df} \{\langle w, h\rangle |$there is a function F s.t. $Dom(F) = S,$ and for $\forall s \in S, \langle w, F(s)\rangle \in s,$ and $h = \bigcup\{F(s)|s \in S\}$ is a function$\}$.

A Language L_{PA} for Attitude Ascriptions

Let L be any DRS-language. Add to L:

1. the discourse referent i (representing the self);
2. conditions of the form s: $Att(x, \mathcal{K}, EA)$, where
   (a) x, s are discourse referents (x for a cognitive agent, s for a state);
   (b) $\mathcal{K}$ is an ADS (Attitude Description Set);
   (c) EA is an external anchor for $\mathcal{K}$, i.e. a set of pairs $\langle y, y'\rangle$, where y is an internally anchored dr of $\mathcal{K}$ and y' is a dr not occurring in $\mathcal{K}$.

This extension of L is called L_{PA}.

ADS-s $\mathcal{K}$: a set of pairs $\langle MOD, K\rangle$, where

1. MOD is a mode indicator; modes we assume here: $MOD \in \{BEL, DES, INT, ANCH\}$;
2. K is a DRS (possibly improper).

ADS-s must satisfy the following conditions:

- if x free in $\langle MOD, K\rangle \in \mathcal{K}$, then there is $\langle MOD', K'\rangle \in \mathcal{K}$ s.t. $K' \prec K$ and $x \in U_{K'}$;

- the relation $\prec$ mentioned in the previous point is <u>well-founded</u> on $\mathcal{K}$ and obeys the *attitudinal hierarchy.*

The attitudinal hierarchy (tentative):

(4)
$$
\begin{array}{ccccc}
 & & & & \mathrm{DES} \\
 & & & \nearrow & \uparrow \\
\mathrm{ANCH} & \rightarrow & \mathrm{BEL} & & ? \\
 & & & \searrow & | \\
 & & & & \mathrm{INT}
\end{array}
$$

Model Theory

Definition 6 Let $\mathcal{K}$ be an ADS, M an intensional model for L, $t \in T_M$. Then

- Each K s.t. $\langle MOD, K\rangle \in \mathcal{K}$ determines a CCP $[\![K]\!]^d_{M,t}$ in M at t;
- Because of the well-foundedness of $\prec_{\mathcal{K}}$ we can associate with each K s.t. $\langle MOD, K\rangle \in \mathcal{K}$ an *information state* $s_{\mathcal{K},M,t}(K)$, as follows:
  - If K has no predecessors under $\prec_{\mathcal{K}}$, then $s_{\mathcal{K},M,t}(K) = [\![K]\!]^d_{M,t}(\Lambda)(= [\![K]\!]^s_{M,t})$; note that K is *proper* in this case;
    (Λ is the trivial information state for M: $\Lambda =_{df} \{\langle w, \emptyset\rangle | w \in W_M\}$);
  - Suppose that $s_{\mathcal{K},M,t}(K')$ has been defined for all K' s.t. $K' \prec_{\mathcal{K}} K$. Then
    $s_{\mathcal{K},M,t}(K) = [\![K]\!]^d_{M,t}(\underline{\bigcup}\{s_{\mathcal{K},M,t}(K') \mid K' \prec_{\mathcal{K}} K\})$.

When is s: $Att(x, \mathcal{K}, EA)$ verified by f in M in w?

<u>Assume</u>: $t \in T_M \cap dur_w(f(s)) \Rightarrow f(x)$ is a cognitive agent a in w (conscious) at t.

We adopt a certain kind of <u>*psychological*</u> <u>*realism*</u>:

M provides for each combination of w, t and a satisfying the assumption, the <u>*attitudinal*</u> <u>*state*</u> that a is in M in w at t.

We assume that this information is given in the form of a function $AS_M(-,-,-)$. What should $AS_M(a,w,t)$ be like?
Our choice: it should be an $ISBAS$ (Information State Based Attitudinal State).

Definition 7 Let M be an intensional model for L. An $ISBAS$ relative to M is a set of pairs $\langle MOD, \pi \rangle$, where

- MOD is a mode indicator;
- π is a regular CCP relative to M.

Definition 8 <u>*Regular CCPs:*</u> A regular $CCP \pi$ has

- A Presupposition set $PRES(\pi)$. This is a set of discourse referents such that an information state $s \in Dom(\pi)$ *iff* $PRES(\pi) \subseteq \mathrm{Base}(s)$;
- a base $Base(\pi)$. This is a set of discourse referents. Whenever $s \in Dom(\pi)$, then $\mathrm{Base}(\pi(s)) = \mathrm{Base}(s) \cup \mathrm{Base}(\pi)$.

An $ISBAS$ $\mathcal{J}$ must satisfy similar conditions as an ADS:

- If $\langle MOD, \pi \rangle \in \mathcal{J}$ and $x \in PRES(\pi)$, then there is π' s.t. $\pi' \prec_{\mathcal{J}} \pi$ and $\langle MOD', \pi' \rangle \in \mathcal{J}$ s.t. $x \in Base(\pi')$;
- the relation $\prec_{\mathcal{J}}$ is well-founded on $\mathcal{J}$ and obeys the attitudinal hierarchy.

In view of these properties we can associate with each π s.t. $\langle MOD, \pi \rangle \in \mathcal{J}$ an information state $s_{\mathcal{J}}(\pi)$. The definition is the analogue of the df. for $s_{\mathcal{K},M,t}(K)$.

Models for L_{PA}

We now extend the notion of a model for L to that of a model for L_{PA}:

Definition 9 M is a model for L_{PA} iff $M = \langle M', AS_M \rangle$, where M' is a model for L and for each $w \in W_M$, cognitive agent $a \in U_M$ and $t \in \mathcal{T}_M$ such that a is conscious in w at t, $AS_M(a,w,t)$ is an $ISBAS$ (*Information State Based Attitudinal State*). ($AS_M(a,w,t)$ identifies the mental state of a in M in w at t.)

Verification of $s\colon Att(x, \mathcal{K}, EA)$:

Definition 10 f verifies $s\colon Att(x, \mathcal{K}, \emptyset)$ in M in w iff there is an alphabetic variant $\mathcal{K}'$ of $\mathcal{K}$ and a function F s.t. for all $t \in T_M \cap dur_w(f(s))$ F is an embedding of $\mathcal{K}'$ into $AS_M(f(x), w, t)$ s.t. for all $\langle MOD, K' \rangle \in \mathcal{K}'$, if $F(\langle MOD, \pi \rangle) = \langle MOD, \pi' \rangle$, then $MOD' = MOD$, and $s_{\mathcal{K},M,t}(K) \preceq s_{\mathcal{J}}(\pi)$.

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